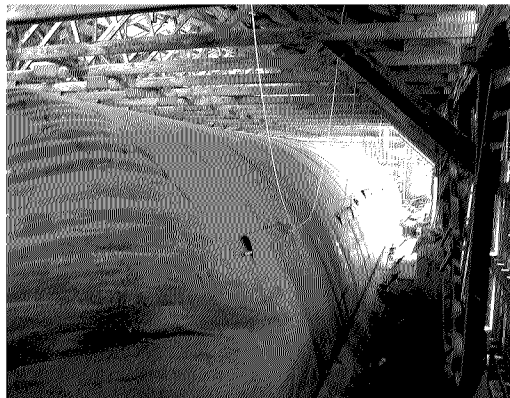
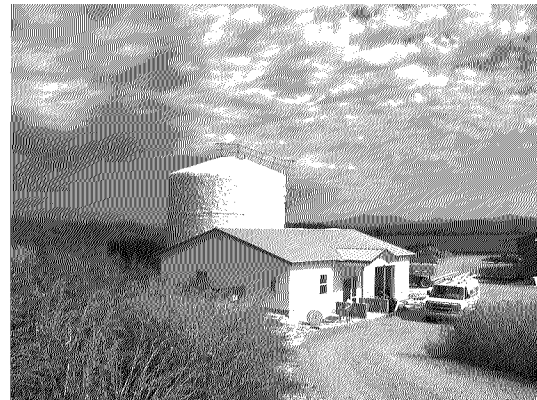
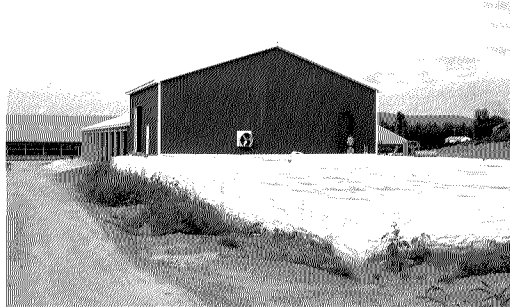


VERMONT'S EXPERIENCE WITH THE ADOPTION OF ANAEROBIC DIGESTION ON FARMS



Daniel L. Scruton
Senior Agricultural Development Coordinator
Vermont Agency of Agriculture, Food and Markets
for the
AgStar National Conference
Sacramento, CA
November 28, 2007

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Introduction

For the past eight years Vermont has been investigating and developing anaerobic digestion systems. Vermont is confident enough in the potential of anaerobic digestion and other renewable energy sources that both the legislative and administrative levels of Vermont state government have committed to the goals of the national 25 X '25 program. That is, achieve 25% of the nations energy supply from agriculture and forestry based renewable energy sources by 2025. The Vermont Agency of Agriculture, Food and Markets is committed to identify, and help develop, technologies that will integrate all of the nutrient management activities on the farm while addressing the environmental issues, and making manure into an income generator for the farm. Our goal is to make the manure handling activities revenue neutral, or better yet, positive to the overall farm operation. This presentation is about a specific part of the Agency's strategy: the role of anaerobic digesters on farms in Vermont.

In 1999, with the help of Senator James Jeffords who secured the funding, the Vermont Public Service Department, and the Vermont Agency of Agriculture, Food and Markets embarked on a joint venture to look at why anaerobic digesters were not in widespread use. The initial movement was toward building a few demonstration sites, but it quickly shifted to a more strategic approach. What were the obstacles and questions that needed to be answered before more systems would, or should, be used? Why did the systems built in the late 1970's and early 1980's fail at such a high rate? The mission was: to identify, and help overcome, the strategic hurdles to widespread adoption of agricultural methane recovery and use technologies.

Initial Work

The first step was to do a literature review to determine the past and current development issues around farm digesters. We discovered the reasons for many of the failures, but equally important,

we were able to show the potential benefits of the technology. We also funded a “Resource Assessment” in which Jeff Fehrs, PE of Williston, VT, investigated the potential organic wastes in Vermont that could be used in farm digesters. He found, not surprisingly, that dairy manure was by far the largest source. Whey, food wastes and other animal manures were more of a niche market that would be useful on some farms but not worth widespread development. If all of the cow manure in the state were digested, it would produce around 28 megawatts of power. The white paper and the resource assessment are available on the Vermont Agency of Agriculture, Food and Markets’ web site, www.vermontagriculture.com. (This assessment was done before the advent of crop digesters and does not include crops but provides useful information on other substrates.)

Feasibility Studies

An article on the Vermont Methane Pilot Project was published in AGRIVIEW (Vermont Agency of Agriculture’s bi-weekly newspaper) asking for farmers that would volunteer to let us do a feasibility study at their farm. There were 16 respondents. Two of these were diversified livestock farms that were too small to be practical. The remaining respondents were given additional information about digesters. Four more dropped out, having concluded that digesters were not practical for their farms. One farmer was considering a new facility and agreed to call us back if they decided to build. (A new barn and digester have since been built.)

Two of the responding farms were small farms that we wanted to investigate the potential for making hot water from biogas.

- One milked 35 cows, and wanted a hot water heating system. The farmer had worked with small scale digesters while in the Peace Corp.
- The other was milking 75 cows and had a bed and breakfast. They wanted hot water heating for the barn and house.

Dr. Stan Weeks, the agricultural engineer retained by the program, did a preliminary engineering analysis, but on both farms, the manure was too dry and it was not cost effective to change to the liquid manure handling, storage and spreading system that would be needed for a digester to work.

Seven of the farms had an “AgStar Farmware” economic analysis done by Jeff Forward, consultant for the Vermont Department of Public Service and Daniel Scruton. The results were: Four had a reasonable cash flow (less than or equal to a seven year payback).

- One of these was built.
- One beds with sand and after preliminary engineering analysis a system was not recommended.
- One was in the planning stage considering a barn complex and wants to install a digester if they decide to build (1000+ cows).
- One is planning expansion and only cash-flows after the expansion (will be 600 cows).

Three had unacceptable rates of return (9 to 13.6 year paybacks).

Feasibility Conclusions

The following bullets are conclusions reached after completing the initial feasibility studies and work done to this point.

- On retrofit scenarios with electrical generator systems, digesters will not be self-supporting from energy value with less than 500 cows, or if the electrical energy rate charged by the utility is under 10 cents per kWh. Further analysis on systems would suggest that even 500 cows is low if using traditional technology at the prevailing wholesale rate (\$0.05 per kWh in 2004).
- Odor control and other benefits may be beneficial enough to sway the dairies that do not have positive cash flow from energy production.
- The payback from building a digester is marginal when compared to other uses for farm capital.
- Hot water systems may fit, but only on small farms with liquid manure systems.

Existing Demonstration Site

Foster Brothers Farm in Middlebury, VT has had an active digester since 1982. When we started our program the Foster Brothers farm digester was down for renovation and needed a new cover. The digester already had dual channels and experienced operators with a strong desire to advance the technology, so they had the potential of being an excellent demonstration site. We set out to answer the questions raised by our literature review to try and develop a simpler, lower cost digester system than is currently available. The system was rebuilt into two side-by-side digesters allowing us the potential to do side-by-side trials.

We have answered many of the initial questions.

- We found that steam injection was a good way to heat manure. It both warmed and mixed the manure at a reasonable cost (about 1 cent per kWh of power produced).
- We found that insulation on the top of a soft-top digester was un-needed as the natural foam layer kept the manure at a stable temperature.
- We discovered that heating pipes inside digester that can lead to plugging and crusting are not needed.
- We learned that it is difficult to get a good seal on concrete digester tanks, especially when re-sealing older concrete tanks.

Hurdles Identified with Initial Review

- **Economic Issues:**
 - The cost/payback comparisons on most commercially available systems were poor to negative. If the system does not cash flow without grants or cost-shares it will probably not produce enough revenue to be sustainable on a long-term basis.
 - Sale to power grid was complicated and the wholesale price low. From a straight economic standpoint most systems did not cash flow with just wholesaling of

electrical power. Depending on the system design, some systems were able to make a profit selling power in excess of farm needs.

- Traditional designs for manure-to-electricity were only suitable for very large farms

- **Management Issues:**

- Traditional designs often required a substantial change in farm management to fit the farm to the system. To be successful, systems need to be developed that will work on a wide variety of management strategies with minimal changes of farm practices.
- Most traditional, and most current, designs have heat pipes traversing the manure in the digester. This makes heat exchange from the engine simple but adds to the maintenance problems as the pipes may build-up with an insulating layer of cooked manure, or the pipes may impede the manure flow. There are also corrosion issues that may occur on the pipes. Municipal digester standards specify heat exchangers are to be outside of the digester for these reasons.
- One of the biggest hurdles was time on the part of the farmer. It took time every day to oversee and maintain the system. The time estimated for a typical digester is ½ hour per day and ½ day per month.

- **Digester Operation Issues:**

- Problematic designs that cause high maintenance.
- Whole manure digesters are prone to crusting and plugging but they also give the highest amount of energy. Designs for whole manure need to have a way of dealing with these issues.
- It is difficult to consistently make concrete gas-tight.
- Gas quality – Manure based biogas is lower in methane than natural gas and only has 50% to 60% of its energy value. It also has H₂S, a corrosive gas that if allowed to condense will form acids that corrode the metal parts of an engine.
- There was little or no existing service industry with experience installing and servicing farm digester systems. There is now a larger service industry, but more is needed.

There have been problems with the systems installed since the 1990's as well. Some of these problems were explainable but many of the systems are not producing the energy they were designed to produce. This emphasizes the need for farmers considering anaerobic digesters to be very selective in the vendor and design they choose.

Economic Solutions

After identifying and reviewing the hurdles to anaerobic digestion, a systematic approach to overcome them was implemented. To improve the financial side of the equation there were two changes in the allowed rate structures to encourage farm-produced energy. The first was improved net metering and the second was payment for the environmental attributes of the power produced.

Net Metering

Net metering is the ability to send power out on to the utility grid, running your power meter backward during times when you generate more than you use, and use the excess power when you need more than you are generating. Each month your statement with the utility reflects the “net” of energy produced minus the energy used. The Vermont legislature has enacted one of the most progressive net metering laws in the country. Many states have net metering that will allow for self-generation through a single meter. But farms that generate more power than they need over time, still need to hard-wire their other buildings to utilize the power. In Vermont, farm systems were expanded to include net metering of multiple meters. Farm systems can produce power at the site most convenient for the generation, and interconnect to utilize the power at any farm-related building within the same utility’s service territory. The utility has to use non-demand, non-time-of-day meters on all locations to simplify net calculations.

Farm related meters include farm buildings and residences owned or occupied by the person operating the farm system, the person's family or farm employees. This allows the farmer to utilize even more of the power they produce at the retail displacement value. At the end of each meter-reading period (generally monthly) the net total of all of the meters in the group will be calculated. If more electrical energy is generated than is used that amount is credited to the farm account and the farmer has up to one year to use it or it reverts to the utility with no compensation to the farmer. If the farm has not generated as much power as it has used they can pull from savings in their bank of power. If they have no bank to use the farm pays for the under-generated power at the normal rate.

The utility can charge reasonable fees for interconnection, special meter reading, accounting, account correcting and account maintenance of farm system net metering arrangements. They can also charge for line improvements, if the capacity of the distribution system is insufficient for the designed generation. (This is unlikely on an existing farm as the distribution feeding the system is designed to deliver peak power and net metering is going to be generating the average needed load.)

The farm needs to file an application for a certificate of public good, including all of the information about the system with the state Public Service Board. The farm must also have a single individual that is the contact for net metering issues, means to settle any disputes in the group, give the utility 30 days to add or remove accounts from the group, a plan on how accounts will be added or removed from the group and be the contact with the utility on all billing issues.

On systems that are designed to produce more power than they need the farm owns the renewable energy credits. On systems that will not produce as much power as they need the utility owns the renewable credits.

A farm with a net metering system may also contract with the utility with options for purchasing any or all of the power produced.

Engineering Benefits to Net Metering

There are numerous engineering benefits to net metering. Generators and digesters can be designed for average power needs, not peak power needs. This has many ramifications. You do not need to design any gas storage capacity, as the genset can produce at a steady level. The genset will always be running at optimal output levels. With load following systems on dairy farms, milking times use very large amounts of power and times between milkings uses very little. This requires the genset to run at inefficiently low output levels during off-peak times.

Digester systems can be designed for the amount of gas needed for the farm's energy needs. As an example, a 750-cow dairy could produce all of the electricity they need with a system that is only digesting the liquid fraction. A liquid only digester is simpler to operate, as there will not be a need to adjust the manure to higher or lower solids content to assure trouble-free operation. The separated solids can be land applied or composted into soil amendments or bedding. Many large farms pay as much for bedding as they do for electricity. The genset will be smaller as it only needs to produce average power needs. This will save both in the cost of the genset but also in the cost of the interconnect wiring.

Economic Benefits from Net Metering

Not only will there be a reduced cost in the system for the reasons stated above, but the payback is also improved. Single meter net metering, versus load-following, gives the retail displacement of self-generation with the added benefit of providing power displacement even when the system is down for maintenance. The bank of unused power can be used to provide power while the system is maintained. With group net metering there is also the benefit of being able to displace power to other meters related to the farm, even if they are miles away, provided they are on the same utility. This adds to the farmer's pay back of the system by being able to provide power to the garage, dry cow barn, family houses and even as an employee benefit.

The economics are simple to understand. Retail rates pay better than wholesale rates. A 750-cow dairy farm is capable of producing around 1,000,000 kWh of electricity per year from whole manure or around 500,000 kWh from liquid manure off a separator. The milking barn is probably using 400,000 kWh annually at \$0.12 per kWh has an energy charge of \$48,000 per year. For this example the wholesale price is assumed to be \$0.06 per kWh and the renewable premium is \$.04 per kWh. The other farm-related houses, barns and out buildings use an additional 100,000 kWh of power.

The value of power from a group net metered system would be \$60,000. If renewable energy credits were sold for \$0.04 per kWh they would add \$20,000.

The value of power for a self-generation only system is \$48,000 and the system cost would be about \$30,000 - \$50,000 higher than a group net metered system since you need to be able to generate peak power.

The value of power from a wholesale-only system would also be \$60,000 (1,000,000 kWh @ \$0.06) but the system cost would be about \$100,000-150,000 higher than a net metered system as the generator needs to be twice as large and the digester tank needs to be larger, and designed to handle the higher solids of whole manure. If renewable credits were sold for \$.04 per kWh they would be worth about \$40,000. Maintenance on the genset will also be higher. At \$.015 per kWh for maintenance per year, the maintenance cost will be \$7,500 higher than the net meter system.

In conclusion the economics are good, the design is simpler, and with the addition payments from renewable attributes for carbon reduction net metering is an option to be considered in states that allow it.

Payments for Environmental Attributes

Vermont has adopted rules that allow for voluntary renewable energy programs. A company can setup programs to sell renewable power to customers on a voluntary basis. If a utility run program they may not shift any cost over to other customers.

Central Vermont Public Service, Vermont's largest utility, has set up a program whereby they will buy power from farm methane systems and sell it as farm-based renewable power to consumers. The premium (initially at \$.04 per kWh) is paid by the consumer and given to the farm customer. This encourages farms that can produce significantly more power than they can utilize in a net metering scenario an option to build a system that can produce maximum power and sell it all to a single vendor. Vermont's other utilities are investigating a variety of options to encourage renewable energy production and use.

Another approach used in Vermont by Native Energy has been to sell the green attributes (environmental benefits of a project). The green attributes are purchased with an up-front payment for all of the benefits for a set number of years. This approach can be combined with renewable energy credits (REC) to further improve the system payback.

AgRefresh, another Vermont company, is combining the environmental attributes of the generation and the environmental attributes of the other manure handling practices associated with the anaerobic digestion system. This potentially increases the per kWh payback to the farmer. The amount of payment depends on the other practices the farm is doing.

In Vermont, all of these renewable energy premiums are voluntary to the end buyers of the credits or attributes and will continue as long as there is a willing market of individuals and businesses that are willing to voluntarily pay extra for renewable power that is produced on a farm. For now, there is demand that is outstripping supply. **One word of caution is that each farmer needs to carefully weigh all the options offered by the various programs as well as weigh the possible need for the carbon credits if a carbon offset program is enforced on livestock farming.**

ST. Albans Bay Manure Cooperative

A feasibility analysis for the farms in St. Albans Bay was completed to see if a group of smaller farms could combine to gain economy of scale sufficient to make a digestion system practical. There is the equivalent of 10,000 mature cows in the St. Albans Bay region of Vermont. Most of these cows are within about 4 miles of a large correctional facility. The farmers in the area are very interested in putting together a manure cooperative that would do a combined heat and power system with the facility. This would address both: the spreading issues like odor; and nutrient loading. The proposal has been through its initial feasibility study and went out for more ideas from specific companies. One large challenge is that the hauling cost of manure exceeds the energy value of the electricity it can produce. By-products from the manure or a value-added energy component will need to be identified to have systems that can cash flow. Spencer Bennett, the consulting engineer hired by the state, has prepared an initial report that is available on the Vermont Agency of Agriculture, Food and Markets' web site, www.vermontagriculture.com.

Systems Constructed Since 2004

As of November 2007, Vermont had six digester systems operating and producing energy and three research projects. In addition to the Foster Brothers System already discussed the following were also in operation:

The first new system in operation was at the Blue Spruce Farm in Addison, VT and is owned and operated by the Audet family. The system was designed by GHD, Inc., a Wisconsin based firm. The farm has several freestall barns pooling the manure from the milking herd, dry cows and young stock to a central reception pit. It is a whole manure horizontal, mixed plug-flow, digester. The digester is a rectangular concrete tank that has a side-by-side design with the manure flowing in a "U" pattern so that the entrance and exit are at the same end of the unit. The agitation is done through a patented process that utilizes gas taken from the headspace of the digester and blows it into the digester causing an agitation pattern that is perpendicular to the manure flow. The manure is separated as it is removed from the digester. The separated solids are used as bedding, land applied, or sold as compost. This makes a system that will produce both energy and bedding. Dr. John Barlow from the University of Vermont did a split-herd controlled study to determine that digested manure solids are suitable as bedding for milking animals. Three other farms have installed similar GHD systems; Pleasant Valley Farm, Berkshire, VT operated by the St Pierre family; Green Mountain Dairy, Sheldon, VT operated by the Rowell Family; and the Montagne Farm, St. Albans Town, VT operated by Dave Montagne family.

A different style whole manure digester has been installed at the Nordic Farm owned by Clark Hinsdale. It was designed by Dr. Stan Weeks, private consultant; Rob Achilles, Agricultural Engineer for the Vermont Agency of Agriculture, Food and Markets and Daniel Scruton. It is a public domain design so that anyone can use the details of the design to advance digester technology. The barn is an 8-row freestall with 4 automatic milking units (robots). The alleys are automatically scraped to a gravity-flow cross channel that flows into a two-day capacity

reception pit. A pump and grinder system is used to feed the manure through a heat exchanger system. The grinding both adds to the energy efficiency of the systems (over 100 cubic feet of biogas per cow per day) but it also minimizes the chance of top-crust formation. The digester is fed manure automatically about every 10 to 15 minutes utilizing a combination of timers and floats. The steady feeding should maximize digester efficiency and provide a steady output of gas. The heat exchanger is a concrete tank with aluminum tubing traversing through the manure. Water heated by the engine jacket flows through the aluminum tubing and exchanges heat with the incoming manure. The manure is then steam injected to assure it goes into the digester at approximately 38°C (100° F). The digester is a glass-bonded-to-steel silo with no mechanical agitation. It has a conical bottom making sludge removal simple and easing cleanout. The genset is custom built for biogas utilizing a standard industrial engine. The goal of the system was to build a system that would need minimal adjustment by the farmer and uses as many off-the-shelf items as practical.

Thinking Outside the Box

Vermont has several research projects. One is on attached growth digesters by BioProcess, a Rhode Island based remediation company. The system is modular so that the digester and other key components can be factory built, transported to the site and set in place. It will allow for modular component design eliminating the need for site-specific individually designed systems that are predominantly site built. The manure will be separated. The liquid then goes to an external heat exchanger and then to the digester. The digester initially is a two-day retention time (20 days is typical). It is designed with attached growth material that will greatly increase the biological activity in the manure. The liquid will then go through a series of tanks that will drop out the nutrients. This concept could save road damage in the spring by eliminating much of the water hauled to fields in large manure tankers. The biggest challenge has been in identifying a separator adequate to remove enough solids for the system to work. A new separator is currently being installed.

A second research site is being designed by Dr. Guy Roberts of Avatar. The system is centered around 80 cow modules and hopes to be scalable and also include a remediation system in a single building. The pilot system is built and going through start-up. They hope to have a system that will be suitable for 80 to 200 cow farms.

A third research project is being undertaken by Tufts University at a small farm with a bed and breakfast. The engineering students at Tufts are designing a low cost digester system that would be suitable for small farms. This project is still in the planning phase.

Under Construction

There is another system under construction that has been designed by the farmer with some outside assistance. This is a tank-in-a-tank combination vertical plug flow and mixed tank system for 1000 cows at the Gervais Family Farm in Bakersfield, VT. One unique feature will be a single-phase interconnection system that will have a 200 kW single-phase generator selling power to the grid.

There are several systems in the final stages of planning that hope to build next spring including a digester designed for mixed substrates of manure, hay and other wastes. There are also numerous farms investigating anaerobic digestion and other renewable technologies on farms.

Summary

There is an exciting future for anaerobic digestion in Vermont. Vermont has approximately 1.5 megawatts of power coming from anaerobic digestion. This will be a good start toward the goal of the Agency of Agriculture, Food and Markets to move manure from the expense column to the profit column of a farmer's ledger book. This will only happen if we move forward investigating innovative alternatives to traditional designs and uses. It is imperative that we make manure easier to handle, nutrient use more precise, and develop income streams from the manure. If the current market trends continue, over the next five to ten years the Vermont Agency of Agriculture, Food and Markets anticipates 15 megawatts of electrical generation capacity from manure based systems and 30 megawatts from crop based anaerobic digestion systems.

Contact Information

Daniel L. Scruton
116 State St.
Drawer 20
Montpelier, VT 05620-2901
Phone (802) 828-3836
FAX (802) 828-3831
email dan.scruton@state.vt.us